RED HILL
MINING LEASE

ENVIRONMENTAL IMPACT STATEMENT

Section 08
Groundwater

Section 08 Groundwater

The Red Hill Mining Lease is located adjacent to the existing Goonyella, Riverside and Broadmeadow (GRB) mine complex in the Bowen Basin, approximately 20 kilometres north of Moranbah and 135 kilometres south-west of Mackay, Queensland.

BHP Billiton Mitsubishi Alliance (BMA), through its joint venture manager, BM Alliance Coal Operations Pty Ltd, proposes to convert the existing Red Hill Mining Lease Application (MLA) 70421 to enable the continuation of existing mining operations associated with the GRB mine complex. Specifically, the mining lease conversion will allow for:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM).
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM).
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRM.

The three project elements described above are collectively referred to as 'the project'.

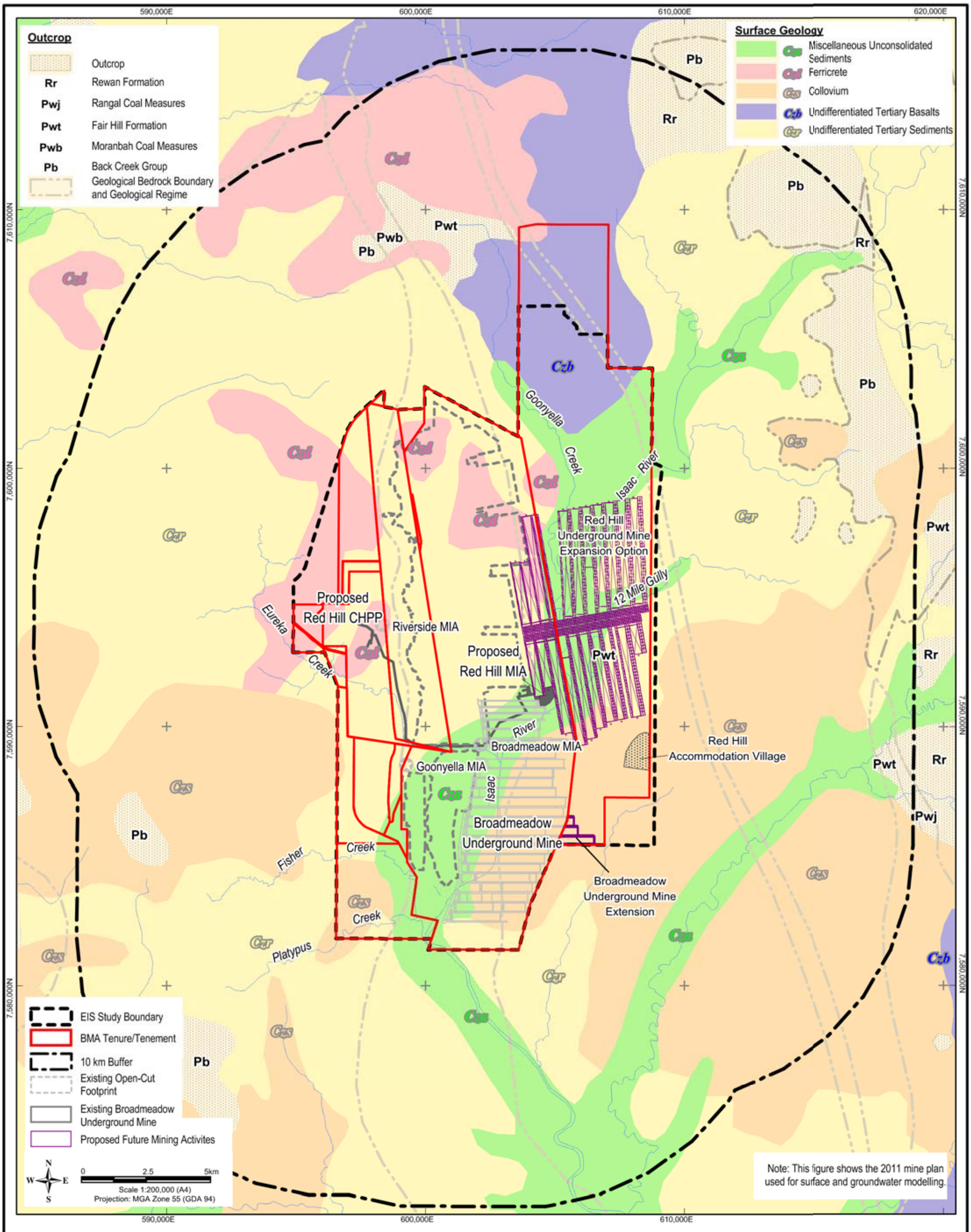
This section provides a summary of the key findings of the project Environmental Impact Statement (EIS) groundwater assessment. The assessment discusses the impact of the project and associated infrastructure on the groundwater regime. A detailed assessment is provided in **Appendix J**.

The scope of work for the groundwater assessment was based on the Terms of Reference (TOR) for the project (Coordinator-General 2013).

The objective of this study was to assess the potential impacts of the proposed project on the hydrogeological regime and, where necessary, identify measures for mitigation and/or monitoring of impacts as specified in the TOR. To achieve this objective, the scope of work included:

- a review of hydrogeological and geological data existing in the public domain, including reports and records held in the Department of Natural Resources and Mines (NRM) and maps published by the Geological Survey of Queensland;
- a review of exploration and monitoring bore data and groundwater reports provided by BMA;
- a review of hydrogeological data held on the NRM Groundwater Database for existing water bores in the area;
- field investigations comprising groundwater sampling and aquifer parameter (variable head) tests;
- survey of existing groundwater facilities (bores, wells) within the BMA properties and in neighbouring properties; and
- an assessment and analysis of all available hydrogeological data through the development of a conceptual hydrogeological model and predictive hydrogeological modelling.

For the purposes of this section, the area within the EIS study boundary is called the 'EIS study area'. The groundwater study however, covered a larger area and this is defined as the 'survey area'. Refer to **Figure 8-1** which shows both boundaries.



Source: © Mapinfo Australia Pty Ltd and PSMA Australia Ltd., © Copyright Commonwealth of Australia (Geoscience Australia) 2006 , © Copyright The State of Queensland (Department of Natural Resources and Water) 2008, © The State of Queensland (Department of Mines and Energy) 2006-2008, © The State of Queensland (Department of Environment and Resource Management) 2010, Bing Maps © Microsoft Corporation and its data suppliers, Images from Client Oct 2011

BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

SURFACE GEOLOGY OF THE STUDY AREA

GROUNDWATER

Figure: 8-1

File No: 42627136-g-1085.wor | Drawn: VH | Approved: CT | Date: 24-06-2013 | Rev.A | A4

8.1 Description of Environmental Values

8.1.1 Legislative Framework and Requirements

The following legislation is applicable to the groundwater study and is covered in further detail in **Appendix J**.

- *Water Act 2000*;
- Water Resource (Fitzroy Basin) Plan 2011;
- *Sustainable Planning Act 2009*;
- *Environmental Protection Act 1994*;
- Environmental Protection (Water) Policy 2009; and
- *Environment Protection and Biodiversity Conservation Act 1999*.

8.1.2 Geology and Groundwater Occurrence

8.1.2.1 Geological Overview

The EIS study area is located within the geological Bowen Basin, an elongate north-south trending basin, which extends from east-central Queensland to northern New South Wales. The basin covers an area of approximately 200,000 square kilometres, and is exposed at the surface over a distance of 600 kilometres from Collinsville in the north to Rolleston in the south, from where it is then overlain by the Surat Basin. It contains a sedimentary sequence of Permian to Triassic age, which attains a maximum thickness of 9,000 metres.

The major geological structure of the survey area is the Collinsville Shelf, a thin accumulation of sediments of the Bowen Basin that forms the boundary of the basin in the west and dips gently (two to eight degrees) and thickens to the east. Folding of the strata is gentle. The eastern boundary of the Collinsville Shelf is marked by a major thrust fault termed the Burton Range Thrust Fault, which is located approximately 10 kilometres east of the EIS study area. This lack of regionally significant geological structures or fault zones distinguishes the Collinsville Shelf sediments from the tightly folded and intruded sediments to the east of the Burton Range Thrust Fault.

Regionally, the stratigraphic sequence is summarised as follows: the Early to Middle Permian Back Creek Group is the oldest Bowen Basin succession observed in the survey area. This is conformably overlain by the Late Permian Blackwater Group, which contains the coal seams of economic interest to BMA. Following deposition of the Blackwater Group was the Triassic Mimosa Group. Tertiary volcanic deposits composed mostly of basaltic lava flows overlie the Bowen Basin successions. These Tertiary volcanic units occur as isolated exposures in the north of the survey area. Extensive Quaternary alluvial deposits are associated with the Isaac River system. A summary of the stratigraphy from the survey area is presented in **Table 8–1** and the local geology is shown in **Figure 8-1**.

Table 8-1 Stratigraphy of the Survey Area

Period		Stratigraphic Unit				Description	Max. Thickness (m)	Presence in Survey Area
Cainozoic	Quaternary	Alluvium				Clay, silts, sand, gravel, floodplain alluvium	37 m in survey area	Confined to present day stream alignments and palaeochannels
	Tertiary	Basalt				Olivine basalt flows	35 m in survey area	Isolated patches in north of survey area
		Suttor Formation				Clay, silts, sand, gravel, colluviual and residual deposits, fluvial and lacustrine deposits	80 m in survey area	Most extensive in the mine areas and to the east
Triassic	Early		Mimosa Group	Rewan Formation		Green lithic sandstone, pebble conglomerate, red and green mudstone	Unknown in survey area	Small area within the north-east
Permian	Late	Bowen Basin	Blackwater Group	Rangal Coal Measures		Sandstone, siltstone, mudstone, coal, tuff, sandstone	100 m	Outcrops or subcrops in the majority of the survey area
				Fort Cooper Coal Measures	Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff	400 m	
					Fair Hill Formation	Labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal		
				Moranbah Coal Measures		Quartzose to sublabile, locally argillacoues sandstone, siltstone, mudstone, carbonaceous mudstone and coal	250 m	
	Early to Middle		Back Creek Group			Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Unknown in survey area	Outcrops west of mines and extends under mined areas to the east

8.1.2.2 Groundwater Occurrence

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. The groundwater regime in the survey area is considered to include:

- Quaternary alluvial aquifers associated with the creeks and Isaac River;
- Tertiary sediment aquifers;
- Tertiary basalt aquifers; and
- Permian-Triassic sedimentary fractured rock aquifers.

The EIS study area is located within the declared Isaac Connors Groundwater Management Area (GMA), as defined in the *Water Resource (Fitzroy Basin) Plan 2011*. Within the Isaac Connors GMA, aquifers in the Quaternary alluvium are known as the Isaac Connors Groundwater Unit 1, with all other aquifers grouped together as the Isaac Connors Groundwater Unit 2. The alluvium associated with the Isaac River in the survey area is defined as the Isaac Connors Alluvium groundwater sub-area of the Isaac Connors GMA. Groundwater supply is not considered to be a major water source in the groundwater survey area. Based on a review of available data, the beneficial use of groundwater in the groundwater survey area is considered to be low due to low sustainable yields and poor groundwater quality.

The occurrence and continuity of the above mentioned aquifers will be highly dependent on the spatial distribution of the corresponding geological units in the area. The conceptual model of the groundwater regime in the survey area is presented in **Figure 8-2**.

8.1.2.3 Quaternary Alluvial Aquifers

Quaternary alluvial deposits in the survey area occur predominantly within the Isaac River floodplains as shown in **Figure 8–3**. Along the Isaac River these deposits consist of clay, sandy clay, and sands and gravels with varying proportions of clay. Sand and gravel deposits are recognised within the waterway beds with the overbank deposits being silty and clayey with minor sand. In the upper catchments of the smaller creeks rock bars are evident (i.e. no alluvium is present), with sand and gravel deposits tending to build up behind the rock bars.

Potential for usable groundwater resources exists within the more permeable sandy and gravely sections of the alluvium, and represents an unconfined to semi-confined aquifer. However, drilling in the survey area alluvium indicates it has variable saturated thickness and does not form a consistent interconnected aquifer. The alluvial aquifer is classed as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The volume of groundwater associated with the alluvium depends on the interconnection of permeable units, saturated thickness, and the ability to store groundwater. During a ground penetrating radar (GPR) survey of the Isaac River at Moranbah North mine (JBT Consulting 2010), accessible during the dry season, it was noted that all test pits dug for the GPR survey within the bed sands were dry, or only damp in the base layer. This suggests that the Isaac River alluvium has limited effective storage, provides limited baseflow to surface water systems (as detailed in **Section 7.2.5**), and does not contain groundwater all year round. Limited groundwater resources, may however, occur in the deeper and relatively narrow parts of the channel. Moranbah Mine is immediately adjacent to Goonyella Riverside and Broadmeadow (GRB) mine complex to the south (refer to **Figure 21-1**).

Due to the generally shallow saturated thickness and the lack of continuity of the more permeable gravel and sand sections, the Quaternary alluvium is not considered a significant aquifer for groundwater extraction (limited sustainable yield). However, during periods of creek or river flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams or other underlying aquifers.

Aquifer hydraulic properties of Quaternary alluvium material (Isaac River bed sands) and flood plain deposits were obtained from investigations undertaken at Moranbah North mine (JBT Consulting 2010). These hydrogeological investigations determined that hydraulic conductivity of the bed sands ranged from 8.9 to 45.4 metres per day. For some investigation sites water dissipated so rapidly that measurements could not be taken, indicating hydraulic conductivity higher than this range. The Quaternary flood deposits (river bank sediments) are generally finer grained than the bed sands, with hydraulic conductivity values between 0.001 and 10 metres per day. This testing indicated that the river bank sediments were less permeable than the bed sands, and would be regarded as being of low to moderate permeability, compared to the higher permeability of the bed sands.

Even though the permeability of some areas of the Quaternary alluvial aquifers is high, the alluvium is not regionally extensive (continuous) and does not maintain a significant saturated thickness and, hence, is considered ephemeral in nature. Accordingly, groundwater extraction at high rates would not be sustainable in the long term (i.e. limited sustainable yields due to limited volumes in storage).

8.1.2.4 Tertiary Sediment Aquifers

The undifferentiated Tertiary sediments and Suttor Formation occurs extensively throughout the survey area, though outcrop is not always continuous, and much of the Tertiary sequence is concealed by younger alluvium and colluvium as shown in (**Figure 8–3**). The Tertiary sediments generally consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. The Tertiary sediments vary in thickness up to approximately 80 metres with a typical thickness of 15 metres in the area of the RHM. The thickness and extent of these Tertiary sediments are variable and for the most part, groundwater resources are limited and typically have poor quality. These Tertiary sediments have limited groundwater environmental values.

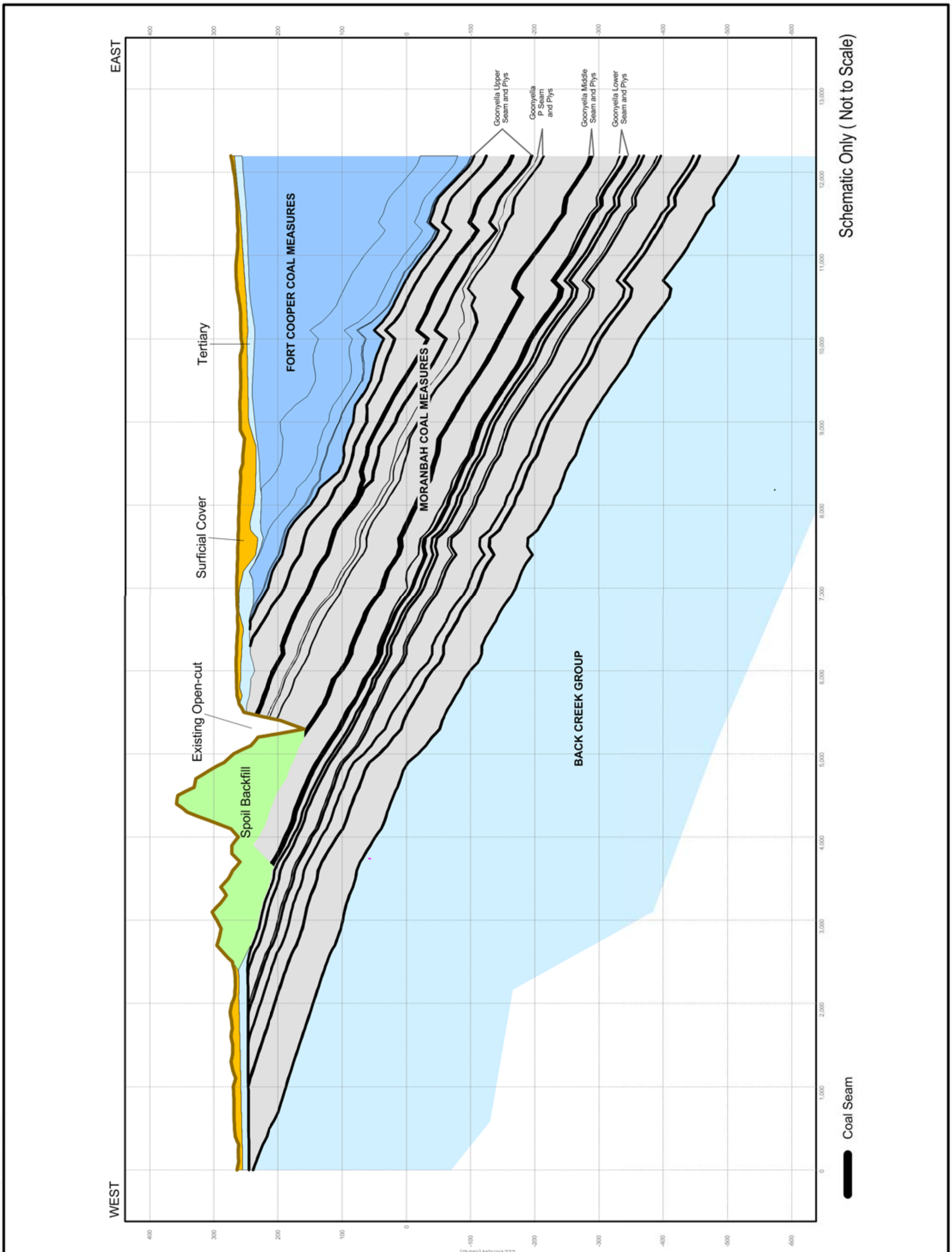
Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments, and represents an unconfined to confined aquifer depending on location, degree of weathering, the nature of the overlying alluvium, and clay content.

Variable permeability within the Tertiary sediment, resulting in different pore pressures, has resulted in occurrences of pit wall instability. However, due to the limited storage the Tertiary sediment aquifers dewater with time. Dry open-cut mining (at the GRB mine complex) indicates that this is not an ongoing problem and that these units readily dewater.

Most of the clean sand and gravel lenses in the Tertiary sediments are permeable but are of limited lateral and vertical extent. Thus, the volume of groundwater stored and the ability to transmit groundwater depends on the particle size of the material and the saturated thickness of the sediments. A review of bore logs within the RHM footprint showed that the Tertiary sediments are dominated by low permeable clays and sandy clays with isolated areas of loose, more permeable sand. An interpreted hydraulic conductivity value of 6.6×10^{-4} metres per day obtained from the variable (falling) head test for monitoring well GYTD7 during investigations for the Airstrip Pit boxcut (IESA 2001) is very low, indicating predominant clay intersected within this bore in the south-eastern most open-cut in the GRB mine complex. No other site specific testing of hydraulic properties has been undertaken on the shallow Tertiary sediments. Installation of monitoring bores (GW1 to GW15) showed that the Tertiary sediments, where intersected, comprise predominantly of clays, containing only very minor sand lenses, and intersected little or no groundwater. Data from exploration drilling also indicates that these sediments are often dry, and occurrence of groundwater in these sediments is sparse. However, where the sediment is coarse in composition, the unit may have localised zones of enhanced hydraulic conductivity.

8.1.2.5 Tertiary Basalt Aquifers

An aeromagnetic geophysical survey has been undertaken over the Bowen Basin by the then Department of Natural Resources and Water. The resultant magnetic data indicates that Tertiary basalt exists as small discontinuous remnants to the south and in the west of the EIS study area, with a larger continuous unit to the north (**Figure 8–3**).



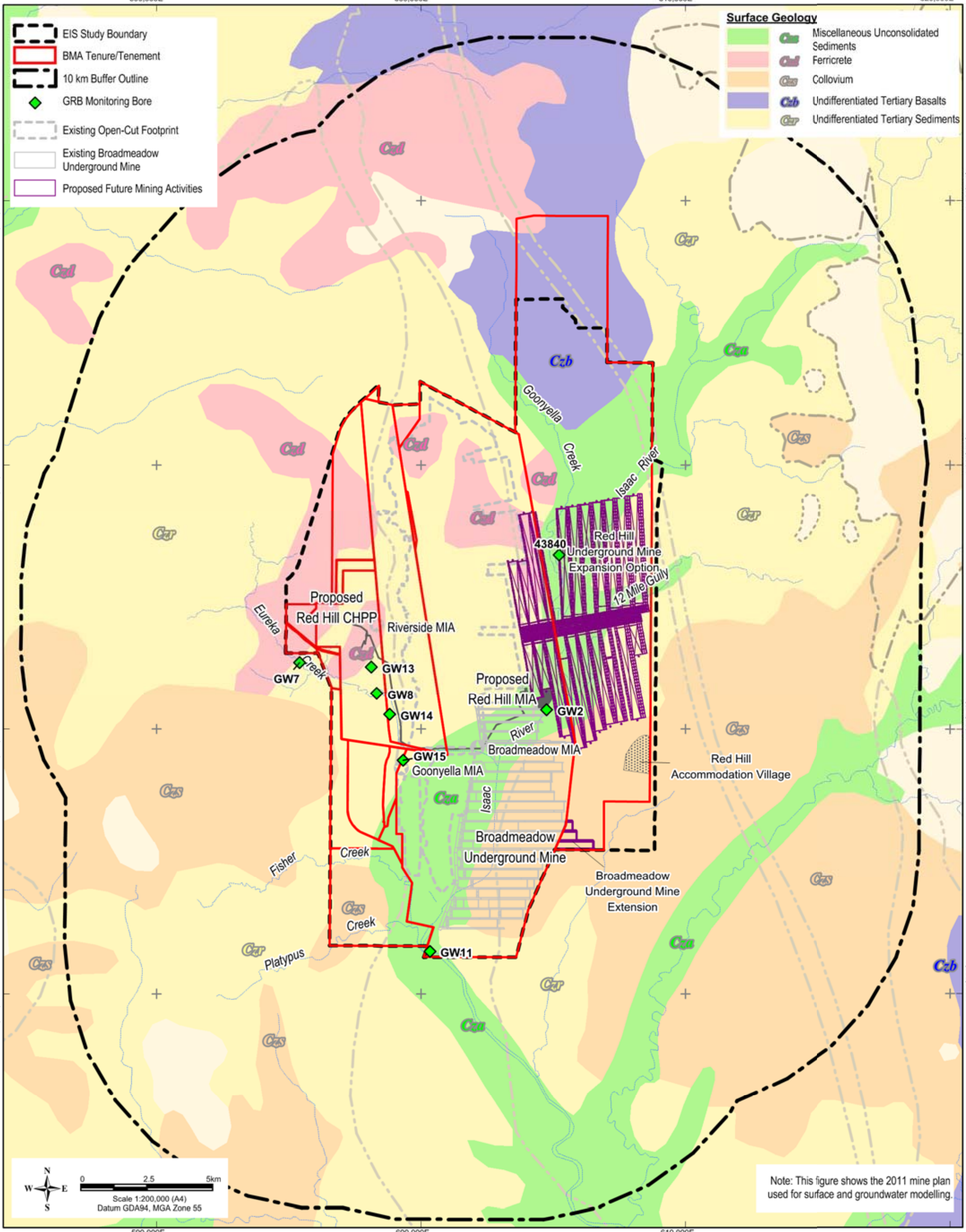
BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

TYPICAL GEOLOGICAL CROSS SECTION

URS | **GROUNDWATER** | Figure: **8-2**

File No: **42627136-g-1125.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev: **A** **A4**



BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

QUATERNARY AND TERTIARY FORMATIONS WITHIN AND SURROUNDING THE EIS STUDY AREA

URS

GROUNDWATER

Figure: 8-3

File No: 42627136-g-1086.wor | Drawn: VH | Approved: CT | Date: 24-06-2013 | Rev.A | A4

For the majority of exploration boreholes that intersected basalt within and adjacent to the RHM footprint, the basalt is highly to extremely weathered, clayey and does not contain groundwater. Where groundwater is present in the tertiary basalt, it is contained in joints, fractures, and vesicles, either confined by low permeability layers or as an unconfined (perched) water table. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass.

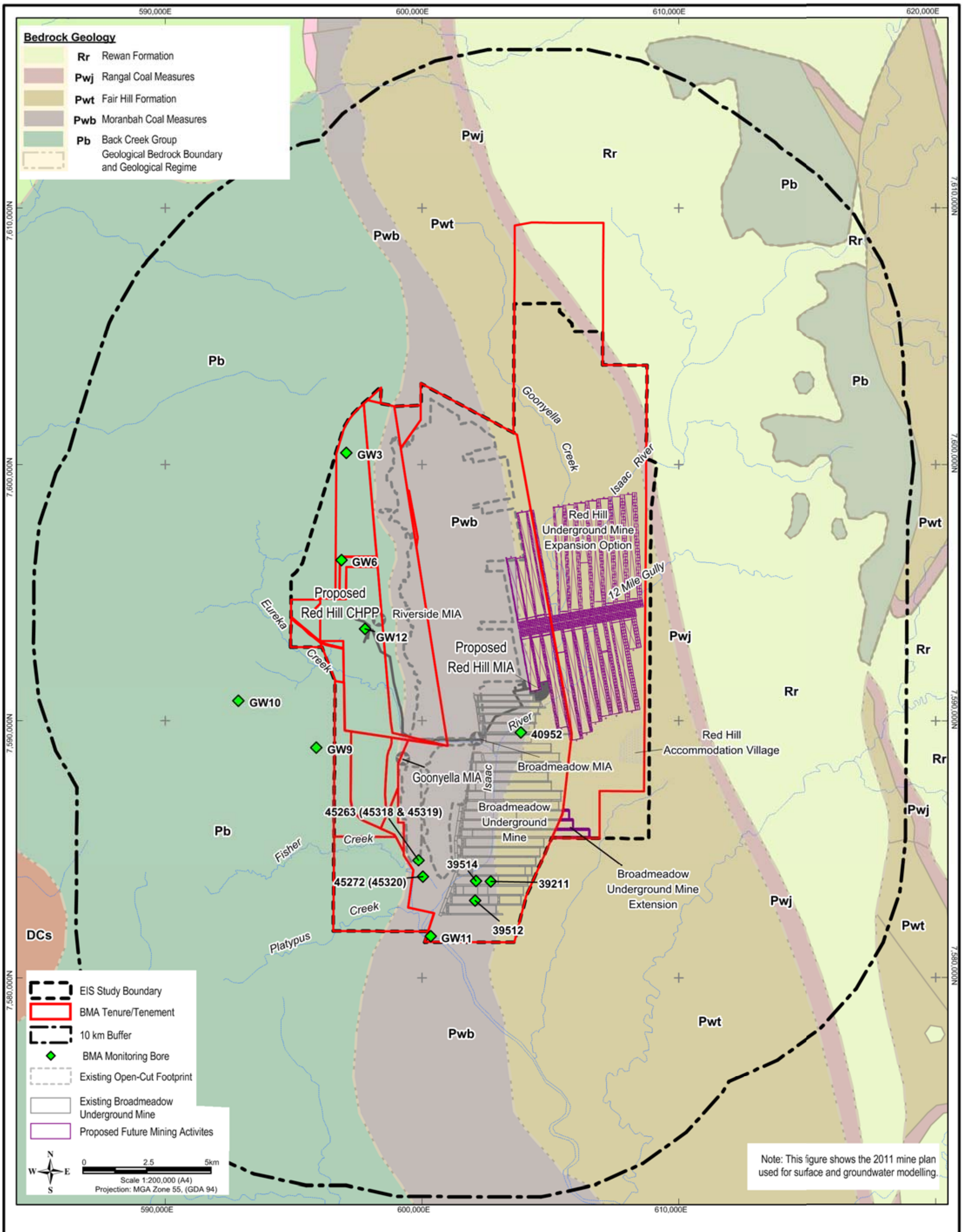
The nature of the Tertiary basalt and, hence its permeability and porosity, is highly variable, depending on the degree of weathering and the intensity and interconnectedness of jointing and/or fracturing. Where the basalt is less weathered and more fractured or vesicular, the unit may have local zones of moderate to high hydraulic conductivity. Hydraulic testing at Moranbah North mine (JBT Consulting 2010) indicated the Tertiary basalt to be moderately permeable with hydraulic conductivity values ranging from one to four metres per day and storage coefficient between 1 x 10^{-2} and 1 x 10^{-4}. On site, interpreted hydraulic conductivity values of 1.21 and 0.48 metres per day were obtained from the variable head test for the existing southern extension of the Airstrip Pit (AGE 2004a) located in the southwest of the EIS study area. The drilling program undertaken as part of this Airstrip Pit groundwater study showed that the Tertiary basalt appears to be highly heterogeneous and discontinuous locally. In the area of the Airstrip Pit, the basalt intersected during drilling was generally not water-bearing; however, for the few holes that did intersect measurable groundwater flows, airlift yields were at most 1.25 litres per second (L/s).

8.1.2.6 Permian-Triassic Strata Aquifers

The Permian-Triassic formations constitute the two dominant Permian formations, which are the Blackwater Group and the Back Creek Group as well as the Triassic Rewan Formation, as described in **Table 8-1** and shown in **Figure 8–4**. As with the rest of the Bowen Basin, the coal seams are the main aquifers within the Permian sequences, with the overburden and interburden rocks in most mines being described as essentially impervious to groundwater movement (AGE 2008). Within the EIS study area, the Goonyella Lower Seam (GLS), Goonyella Middle Seam (GMS) and Goonyella Upper Seam (GUS) coal seams of the Moranbah Coal Measures constitute the most extensive aquifers. These seams have been removed in the majority of the western extent of the EIS study area through open-cut mining. The Triassic Rewan Formation strata occur only in the very northeast of the survey area.

The coal seam aquifers are confined above and below by very low permeability geological formations and movement of water through the aquifer (transmissivity) is likely to be through the more permeable (cleats) coal rather than the confining units. The confining units also have very low vertical hydraulic conductivity (leakance), such that aquifer recharge is limited. Groundwater occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable (either due to high clay content or significant cementing) and form aquitards. The Permian and Triassic strata may, therefore, be categorised into the following hydrogeological units:

- hydrogeologically ‘tight’ and, hence, very low yielding to essentially dry claystone, mudstone, sandstone, siltstone and shale that comprise the majority of the strata;
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence; and
- localised fracture or fault systems which are open and have not been infilled by clay/carbonate deposition.



BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

SUB-SURFACE PERMIAN AND TRIASSIC FORMATIONS WITHIN AND SURROUNDING THE EIS STUDY AREA

URS

GROUNDWATER

Figure: **8-4**

File No: **42627136-g-1087.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4

Hydraulic conductivity values determined for the Moranbah Coal Measures in the survey area are presented in **Table 8-2**. The aquifer testing results indicate that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability. WDS (2011) conducted an engineering study for coal seam degassing prior to mining of the RHM area, using data derived from packer testing in 31 seam/site combinations in the Moranbah and Fort Cooper Coal Measures. This study found that:

- with increasing depth, effective stress increases and permeability decreases;
- with increasing ash (mineral matter), rock stress and effective stress increases and permeability decreases; and
- with increasing gas content, primary permeability decreases.

Hydraulic testing of the interburden units revealed highly variable hydraulic conductivity, ranging from moderately pervious to highly impervious. This is evidence that the Permian formations are heterogeneous, having discrete zones of higher permeability associated with fracture/fault systems (alteration) isolated by the very low hydraulic conductivity in the majority of the interburden and overburden.

Interpreted hydraulic conductivity values determined for the Back Creek Group during the EIS investigations were between 0.002 and 0.1 metres per day.

Table 8-2 Interpreted Hydraulic Conductivity of Permian Strata Aquifers

Area of Investigation	Permian Strata Investigated	Method of Determination	Hydraulic Conductivity (m/day)
Goonyella No2 (Rust PPK 1996)	GMS	Pumping test	0.003 to 0.034
	GMS	Packer test	0.009 to 0.085
Airstrip boxcut (IESA 2001)	GLS	Falling head slug test	0.06 to 0.47
Goonyella longwall development (AGE 2002)	GMS	Calibration of groundwater numerical model	0.0009 to 0.1
Airstrip south boxcut (AGE 2004a)	GLS	Falling head slug test	0.06 to 0.80
		Calibration of groundwater numerical model	0.82
Ramp 8 (AGE 2004b)	GLS	Shut in pressure test	0.10
		Falling head slug test	0.01 to 0.03
	Interburden	Falling head slug test	2E-05 to 0.33
Red Hill Mining Lease	Interburden	Constant head core test	Horizontal 2E-06 to 3E-05
			Vertical 9E-07 to 9E-05

8.1.3 Groundwater Levels and Flows

8.1.3.1 Quaternary Alluvial Aquifers

The alluvial aquifers are considered to be strongly linked to surface water (SKM 2009). The Isaac River and creeks within the EIS study area are ephemeral and recharge of the alluvium is by:

- recharge from surface water flow or flooding (losing stream); and
- surface infiltration of direct rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Available data suggests that water infiltrates / drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. This saturation is sporadic, producing semi-permanent, localised and thin aquifers. Groundwater discharge from the alluvium occurs through:

- evapotranspiration from vegetation growing in the creek beds and along the banks;
- baseflow from the permeable sands and gravels; and
- infiltration and recharge to the underlying older formations where the alluvium occurs over more permeable zones within these units.

Owing to the paucity of data for the Quaternary alluvium, limited information exists regarding groundwater flow; however, at a regional scale groundwater flow within the aquifer is expected to follow topography and drainage patterns. Drilling on site indicates that, where groundwater does occur, depth to groundwater in the Quaternary alluvium was approximately 11 to 13 metres below ground level (mbgl). The groundwater level in the alluvium, measured in a study by Thatcher (1976), was about 20 metres above the piezometeric (confined) water level in the coal at the same location. These groundwater levels indicate a marked separation between the perched alluvium groundwater level and the piezometeric levels associated with the deeper confined coal seam aquifers. The alluvium, therefore, is not recharged by upward groundwater movement. It is therefore considered that any depressurisation of the confined aquifer (reduced piezometeric pressures) below the alluvium would have limited impact on the perched overlying water table(s).

8.1.3.2 Tertiary Sediment Aquifers

Recharge processes in the Tertiary sediment aquifers are via:

- direct infiltration of rainfall and overland flow where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface; and
- overlying Quaternary alluvial aquifers.

Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams); evapotranspiration; and
- groundwater extraction.

Owing to the paucity of data for the Tertiary sediments, limited information exists regarding groundwater flow; however, regionally groundwater flow within the aquifer is expected to be a subdued reflection of topography. The depth to groundwater in monitoring wells on site in the Tertiary sediment aquifer is typically less than 15 mbgl (IESA 2001).

8.1.3.3 Tertiary Basalt Aquifers

The depth of the basalt, the generally clayey nature of the weathered upper basalt, and the Tertiary sediments associated with the basalt, indicate that effective recharge is low. Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall in rock outcrop areas where no substantial clay barriers exist in the shallow subsurface; and
- vertical seepage or through flow from overlying or adjacent alluvial or Tertiary sediment aquifers.

Primary discharge mechanisms in the Tertiary basalt aquifers are likely to be:

- down gradient Tertiary basalt outcrop areas;
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams);
- evapotranspiration; and
- groundwater extraction.

Depth to groundwater in the Tertiary basalt aquifers have historically been measured at between 23 and 34 mbgl (AGE 2004b). Due to the discontinuous nature of the basalt, groundwater flow direction cannot be determined on a regional scale.

8.1.3.4 Permian-Triassic Strata Aquifers

Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall and overland flow in outcrop and sub-crop areas;
- downward seepage or through flow from overlying or adjacent alluvial or Tertiary aquifers where no significant clay barriers exist; and
- leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

Primary discharge mechanisms in the Permian-Triassic strata aquifers are likely to be:

- downgradient Permian-Triassic strata outcrop areas;
- through flow into adjacent (outcropping or sub-cropping coal seams) or seepage into underlying aquifers (via structural discontinuities); and
- groundwater extraction (coal seam gas (CSG) extraction, groundwater extraction, and other mine dewatering activities).

Evidence from groundwater level measurement for the coal seam aquifers during previous investigations suggests the levels (piezometeric pressures) were slightly different for each seam, with the GUS seam being one to two metres higher than the GMS seam, and the GLS seam being up to 14 metres lower than the GMS seam. This variation in hydraulic heads between coal seams indicates the confining (no flow aquitard) nature of the interburden (above and below) which separates the coal seam aquifers. These marked differences in piezometeric pressure indicate little or no hydraulic connection between coal seams and thus limited potential for induced flow. Induced flow can occur where coal seam aquifers are depressurised resulting in the groundwater flow towards the depressurised unit from above or below.

The groundwater levels varied from 15 to 50 mbgl. Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers appears to have been from the north and west to the south and east across the site. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the west of the site and discharge occurring downgradient in the Isaac River subcatchment in the Bowen Basin. The current groundwater flow pattern has been altered locally with groundwater flow towards existing mine pits and underground workings due to mine dewatering and depressurisation. Groundwater modelling (AGE 2002) and groundwater level measurements indicate that groundwater levels are affected by mining induced drawdown up to 2.7 kilometres from the mine workings.

Groundwater levels in monitoring bores in the interburden between coal seams are variable. Groundwater levels are generally above the horizon in which the groundwater was intersected showing that these zones are mostly confined. The observations of the interburden water bearing horizons lead to the conclusion that some horizons are discontinuous and, where the horizons are continuous, they have heterogeneous hydraulic properties creating isolated, lens-like aquifers. Due to the heterogeneity and discontinuity of the interburden aquifers within the Permian strata, the groundwater flow direction cannot be determined on a regional scale for these aquifers.

No data exists on the seasonal fluctuations of groundwater level within the Permian-Triassic aquifers. However, due to the depth and confined nature of these aquifers, they are expected to show a subdued response to recharge or discharge.

8.1.4 Groundwater Use

The survey area is located within the declared Isaac Connors GMA, as defined under Section 6, Schedule 3 and Schedule 4 of the *Water Resource (Fitzroy Basin) Plan 2011*. Within the declared management area, water licenses and/or development permits are not required for stock or domestic bores (development permits are self-assessable). The NRM also excludes all sub-artesian groundwater monitoring bores from the requirement for development permits (pers coms William Legg, NRM). In Queensland, all wells deeper than six metres, including monitoring wells, must be constructed by, or under the supervision of, a licensed water bore driller who has the correct endorsements on their licence for the type of activity being performed. It is a requirement of the *Water Act 2000* (Water Act) that a licensed water bore driller submit the records of the drilling and installation of a water well to NRM within 30 days of completion of the well. These records are entered in NRM database.

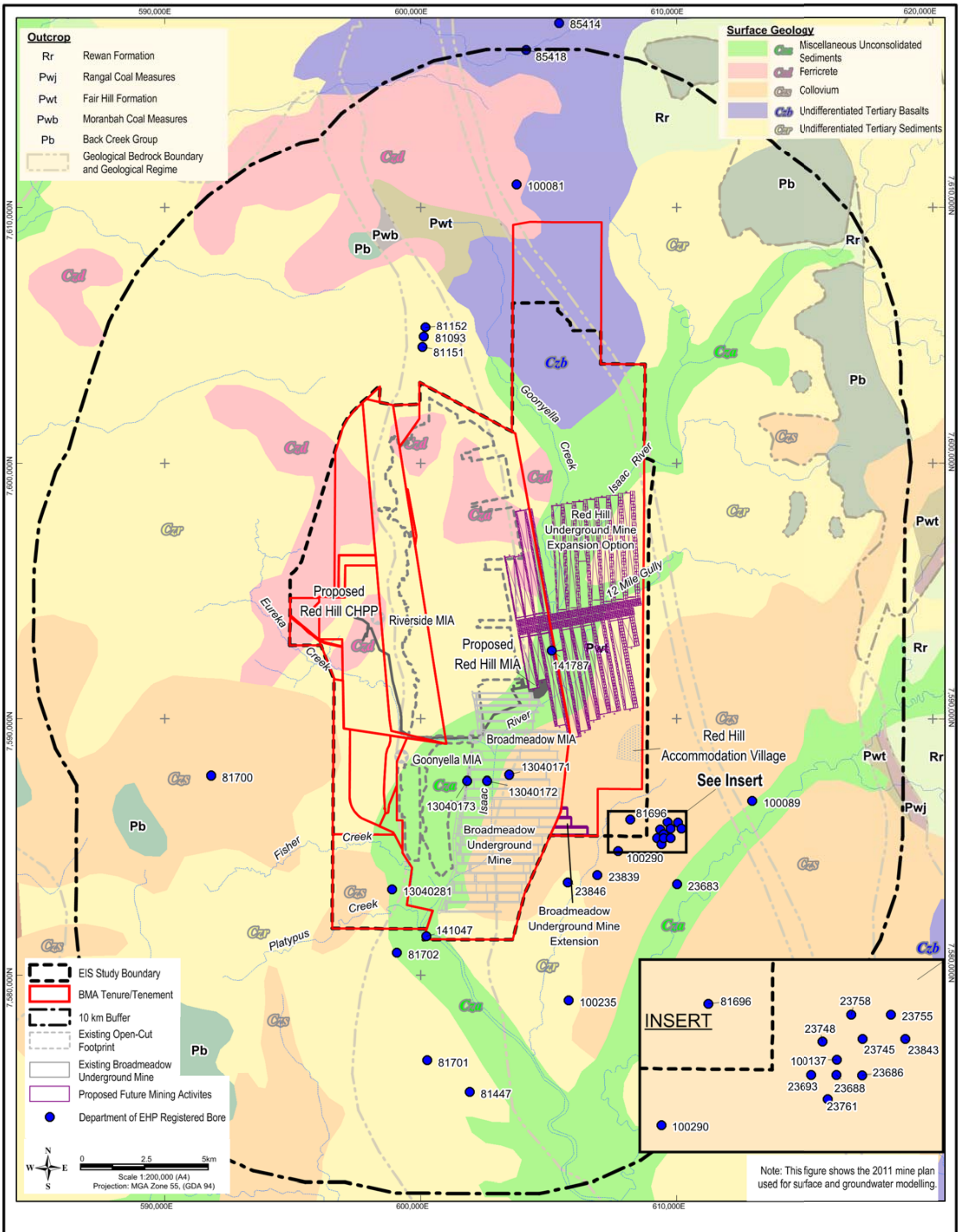
From a search of the NRM groundwater database, 31 bores are registered within 10 kilometres of the EIS study area, as shown on **Figure 8-5**. Of the 31 bores, 27 have been installed for private use, and four have been installed by NRM for groundwater monitoring and assessment (three of which have been abandoned and destroyed). Of the 27 bores installed for private use, 16 were installed for CSG exploration in the Moranbah or Fort Cooper Coal Measures, with four of the seven other private bores in these formations being abandoned and destroyed. No stratigraphic or casing description information has been included in the NRM database for the three remaining non–CSG bores and, accordingly, it is not certain from which aquifer these bores extract groundwater. No information exists in the database on the normal pumping rates of these bores, or the drawdown that occurs during pumping. The current use of the bores is not specified in the NRM database; however, typical groundwater use in the area is for stock watering owing to the variable salinity levels and generally low yields. No dewatering for CSG extraction is currently undertaken within the EIS study area, however, CSG exploration has been undertaken in the area and producing CSG wells are located to the south-east of the project.

A groundwater bore census was conducted on properties within and surrounding the EIS study area to collect information on groundwater bores installed before registration was a requirement, and additional information on bores registered in the NRM database. Four bores were recorded during the census: two on ‘Denham Park’ and two on ‘Broadmeadow’. The location of these bores is shown on **Figure 8-5** and summary of bore details are provided in **Table 8-3**. The bores on ‘Denham Park’ intersect the basalt aquifers to the northwest of the EIS study area; however, the basalt does not extend into the project infrastructure or mine areas and so these bores are unlikely to be impacted by it. The bores on ‘Broadmeadow’ are considered to be constructed into the base of Tertiary (basal sand/sandstone) or the top of the Permian formations.

Table 8-3 Summary of Information Collected During Bore Census

Property	Bore Name	Drilled Depth (mbgl)	Depth to Water (mbgl)	Water Use	Pumping Rate (L/s)	Landholder Description of Water Quality
Denham Park	Tex’s Bore	118.9	34.13	Domestic and stock watering in drought	4.5	
Denham Park	Old Mill Bore	117.1	90.66	Stock watering	1.9	
Broadmeadow	Skeleton Bore (NRM Registration 81696)	63.7	28.41	Stock watering when required	1.3	‘Good’
Broadmeadow	Cleanskin Gully	25.34	14.02	Stock watering when required	2.6	‘Good’

There are no dewatering bores currently operating on the GRB mine complex. There have been groundwater dewatering bores in the past for the establishment of GRM boxcuts; however, these were not replaced as they were mined out because groundwater inflow to the open-cut pits is limited once mining is established. Due to the large surface area of the open-cut pits and the significant excess of evaporation over rainfall in the area, groundwater which seeps from the coal seams in the open pits mostly evaporates, with limited amounts collected in sumps and pumped to the mine water system for reuse. Groundwater is not actively dewatered in advance of mining in the BRM, with seepage collected in sumps and pumped to the surface into the existing mine water system for reuse. Total groundwater contribution rates to the mine water system are not monitored as these are at low levels.



BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

LOCATION OF DEPARTMENT OF EHP REGISTERED BORES AND BORE CENSUS

URS

GROUNDWATER

Figure: **8-5**

File No: **42627136-g-1088.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4

8.1.5 Groundwater Quality

Groundwater samples were collected for chemical analysis from piezometers installed around the site during previous site investigations and for this groundwater study.

The physico-chemical results obtained during groundwater sampling within the survey area, which have been summarised and presented in **Table 8-4**, indicate the groundwater chemistry is typically neutral to weakly alkaline (pH) for all formations. The Tertiary and Permian formations have variable salinity (measured as electrical conductivity), ranging from brackish to saline, while the groundwater quality within the alluvium is fresh.

It should be noted that the depth of the aquifer and its distance from the area of recharge are likely to influence the result at a given sample point, as salinity appears to increase with depth and the distance from the area of recharge. Based on ANZECC/ARMCANZ (2000) guideline values, the groundwater may be suitable for livestock drinking water and irrigation of salt tolerant crops. However, the low yield typical of the aquifers would preclude use for large scale irrigation. Median groundwater salinity values were greater than the 50^{th} percentile water quality objective (WQO) nominated in the *Environmental Protection (Water) Policy 2009* (EPP (Water)) for groundwaters in the Isaac River Sub-basin (zone 34, which covers part of the survey area). The limited dataset does, however, indicate that groundwater results cover a wide range for each unit (due to depth, distance from recharge, and age of water). The lower end of the range results are within the WQO.

Table 8-4 Physico-Chemical Results for Aquifers in the Survey Area

Aquifer	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Quaternary Alluvium	2	521-561		6.88-7.55	
Tertiary Basalt	3	2,670-15,384	13,100	8.19-8.67	8.38
Tertiary Sediment	1	5,060		9.30	
Permian Interburden	6	7,030-18,800	12,805	7.38-8.38	8.06
GMS	5	2,450-16,127	9,110	6.65-7.90	7.12
GLS	30	387-31,300	24,050	2.71-8.76	7.99
Back Creek Group	3	4,530-24,030	22,660	5.98-6.79	6.74
Undifferentiated from airlift sampling during exploration drilling	75	100-30,000	12,593	6.89-9.18	7.68
ANZECC/ARMCANZ (2000) upper limits[1] • irrigation • livestock – cattle		2,900-5,200 8,300-16,700[2]			
EPP (Water) [3] – 50^{th} percentile • shallow groundwater (<30 m) • deep groundwater (>30 m)		2,150 6,100		7.75 7.80	

Note 1: ANZECC/ARMCANZ (2000) Water Quality Guidelines for livestock drinking water (cattle) and irrigation of salt tolerant crops.

Note 2: Electrical Conductivity value based on TDS value for livestock (EC [µS/cm] = 1.67 × TDS [mg/L]).

Note 3: EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34.

Results of the analyses of groundwater samples from the Permian Moranbah Coal Measures and Back Creek Group indicate that the groundwater salinity is principally due to elevated levels of sodium and chloride ions as shown in **Table 8-5**. The Back Creek Group groundwater contains a relatively higher proportion of sulphate due to marine influence during deposition compared to the Moranbah Coal Measures. The groundwater from the Quaternary alluvium is dominated by sodium and bicarbonate ions, and has a lower salinity than the groundwater of the Permian formations.

8.1.6 Assessment of Environmental Values

The location of the proposed project is within the Isaac River sub-basin of the Fitzroy Basin as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries (irrigation, farm supply, stock water); and
- cultural and spiritual values.

The existing groundwater environment, within the groundwater survey area, has been assessed against these environmental values.

8.1.6.1 Biological Integrity of a Pristine or Modified Aquatic Ecosystem

The local area within and around the Broadmeadow panel extensions and the RHM footprint has largely been cleared for agriculture, predominantly beef cattle grazing, as well as for coal mining purposes. These farming and mining practices modify the landscape, affecting the volume and rate of rainfall runoff, the flow characteristics of the creeks, and recharge to groundwater. As such, the aquatic ecosystems of the area have been modified.

Groundwater dependant ecosystems (GDE) are ecosystems which have their species composition and natural ecological processes determined in part by groundwater. The groundwater parameters that sustain GDEs are flow rate, level, and quality, with dependence potentially being a function of one or all of these factors.

The water level measurements undertaken on site indicate that the water table within all aquifers on site is generally greater than 10 mbgl, although the depth to water within the bed sands (ephemeral aquifer) in watercourses is less than this when saturated. These depths to groundwater, and the lack of permanent springs in the area, indicate that GDEs are not likely to exist in the vicinity of the site. This was confirmed in **Section 9.6.3.2**. The vegetation species and regional soil/geology types suggest that the level of groundwater dependence is likely to be relatively low (known as opportunistically groundwater dependent) and vegetation is likely to be able to satisfy plant water requirements using retained soil moisture. Water available to ecosystems may include a mix of groundwater with soil water (unsaturated zone) and surface water.

In addition the depth of groundwater limits any potential use by listed or threatened species and migratory birds. Any potential changes in groundwater levels as a result of mine dewatering are therefore not considered to impact on listed or threatened species and migratory birds.

Table 8-5 Summary of Water Chemistry for Representative Bores on Site

Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP (Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP (Water) – 50th Percentile, Deep (>30 m depth)[1]	ANZECC/ ARMCANZ (2000) and DERM (2009) - Freshwater Ecosystems[2]	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water[3]	NHMRC (2011) - Human Drinking Water[4]	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)
Major Ions																	
Sodium	747	1,100	ne	ne	30[6]	13	40	1,096	3,560	3	824	3,470	4,400	2	40	-	94
Calcium	84	145	ne	1,000	ne	13	<0.01	49	469	3	34	214	422	2	13	-	39
Magnesium	108	115	ne	ne	ne	13	<0.01	25	570	3	86	542	805	2	7	-	20
Potassium	ne	ne	ne	ne	ne	13	1.4	6	28	3	29	35	38	2	3	-	3
Chloride	1,309	1,900	ne	ne	ne	13	64	2,024	7,510	3	1,390	7,000	9,750	2	10	-	71
Bicarbonate	536	330	ne	ne	ne	13	85	497	5,656	3	10	417	774	2	180	-	293
Sulphate	140	138	ne	1,000	200[6]	13	0.2	4	626	3	223	692	763	2	6	-	26
Fluoride	0.28	0.155	ne	2	1.5	11	<0.1	0.2	1.2					2	0.2	-	0.4
Nutrients																	
Nitrite + Nitrate as N	0.95	2.15	0.015	ne	ne	13	0.02	0.2	0.9	3	0.05	0.09	0.33	2	0.125	-	0.315
Total Phosphorus as P	ne	ne	0.03	ne	ne	13	0.03	0.5	5.08	3	0.78	1.49	1.56	2	0.47	-	0.75
Metals (Dissolved)																	
Aluminium	ne	ne	0.055	5	ne	13	<0.01	<0.01	0.1	3	0.04	0.05	0.05	2	0.05	-	<0.1
Antimony	ne	ne	ne	ne	0.003	2	0.004	-	0.007	3	<0.001	0.004	0.004	-	-	-	-
Arsenic	ne	ne	0.013	0.5	0.01	7	<0.001	0.002	0.024	3	0.001	0.008	0.013	2	<0.001	-	<0.01
Barium	ne	ne	ne	ne	2	2	0.168	-	0.313	3	0.046	0.095	0.107	-	-	-	-
Beryllium	ne	ne	ne	ne	0.06	2	<0.001	-	<0.001	3	<0.001	<0.001	0.001	-	-	-	-
Boron	ne	ne	0.37	5	4	7	<0.1	0.26	0.6	3	1.51	1.82	3.32	2	<0.1	-	0.1
Cadmium	ne	ne	0.0002	0.01	0.002	7	<0.0001	0.0002	0.005	3	0.0002	0.0005	0.0006	2	0.0002	-	<0.005
Chromium	ne	ne	0.001	1	0.05	7	<0.001	0.002	0.01	3	0.002	0.003	0.004	2	0.002	-	<0.01

Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP (Water) – 50th Percentile, Shallow (<30 m depth)[1]	EPP (Water) – 50th Percentile, Deep (>30 m depth)[1]	ANZECC/ ARMCANZ (2000) and DERM (2009) - Freshwater Ecosystems[2]	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water[3]	NHMRC (2011) - Human Drinking Water[4]	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[5]	Min (mg/L)	Median (mg/L)	Max (mg/L)
Cobalt	ne	ne	ne	1	ne	7	<0.001	0.003	0.01	3	0.018	0.02	0.08	2	<0.001	-	<0.01
Copper	0.01	0.03	0.0014	1	2	7	<0.001	0.002	0.01	3	0.001	0.002	0.004	2	<0.001	-	<0.01
Gallium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Iron	0.03	0.05	ne	ne	ne	13	<0.01	<0.05	1.2	3	<0.05	0.12	1.94	2	<0.05	-	<0.05
Lead	ne	ne	0.0034	0.1	0.01	7	<0.001	0.001	0.01	3	<0.001	<0.001	<0.001	2	<0.001	-	<0.01
Lithium	ne	ne	ne	ne	ne	2	0.041	-	0.136	3	0.206	0.276	0.41	-	-	-	-
Manganese	0.01	0.05	1.9	ne	0.5	13	0.002	0.18	1.23	3	0.958	0.991	1.07	2	0.037	-	0.16
Mercury	ne	ne	0.00006	0.002	0.001	2	<0.0001	-	<0.0001	3	<0.0001	<0.0001	<0.0001	-	-	-	-
Molybdenum	ne	ne	ne	0.15	0.05	7	<0.001	0.01	0.021	3	<0.001	0.002	0.003	2	<0.001	-	<0.01
Nickel	ne	ne	0.011	1	0.02	2	0.002	-	0.033	3	0.009	0.028	0.131	-	-	-	-
Selenium	ne	ne	0.005	0.02	0.01	7	<0.01	<0.01	0.05	3	<0.01	0.01	0.03	2	<0.01	-	<0.01
Strontium	ne	ne	ne	ne	ne	2	1.75	-	3.86	3	0.675	8.52	10.7	-	-	-	-
Thorium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Titanium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Uranium	ne	ne	ne	0.2	0.017	2	0.002	-	0.005	3	<0.001	0.002	0.003	-	-	-	-
Vanadium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Zinc	0.015	0.025	0.008	20	ne	7	<0.01	0.013	0.13	3	0.05	0.054	0.174	2	0.008	-	0.02

Note 1: EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater.
Note 2: ANZECC/ARMCANZ (2000) and DERM (2009) trigger values for moderately disturbed upland stream freshwater ecosystems.
Note 3: ANZECC/ARMCANZ (2000) guidelines for livestock watering of beef cattle.
Note 4: NHMRC (2011) health based guidelines for drinking water.
Note 5: Number of samples.
Note 6: EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for drinking water.
ne – No guideline value established.

Although groundwater investigations indicate very low potential for groundwater resources to be physically available to support GDEs, the groundwater analytical results, as presented in **Table 8-5**, have been assessed against the water quality objectives in the EPP (Water) (for Zone 34, which includes the Moranbah area), ANZECC/ARMCANZ (2000) and Queensland water quality guidelines (DERM 2009) for the protection of moderately disturbed freshwater ecosystems, central region, upland streams. This allows consideration of whether the groundwater resources in the area are of a sufficient quality to provide environmental value to possible GDEs via flow into surface water bodies.

The assessment of groundwater quality using these surface water guideline values has an inherent level of conservatism due to the assumptions made regarding the behaviour, fate and transport of the analytes detected in groundwater and the subsequent effects in the surface water ecosystem. The existing groundwater quality concentrations are above the water quality guidelines for freshwater ecosystems for some dissolved metals and nutrients, and the median concentrations of most of the major ions are above the 50th percentile WQO for the Isaac River sub-basin for the deeper groundwater (Back Creek Group and Moranbah Coal Measures). These existing exceedences indicate that even if the deeper groundwater was physically available to support GDEs, it has low environmental value for sustaining the biological integrity of aquatic ecosystems. Shallow groundwater in the alluvium may, however, sustain aquatic ecosystems as flow to GDEs or surface water bodies although shallow aquifers are ephemeral, only existing for short periods after recharge.

8.1.6.2 Suitability for Recreational Use (Primary Recreation)

This category of environmental value is considered not applicable to groundwater *in situ*. There are also no registered groundwater springs in the area that could be considered for recreational use. Groundwater seepage from the alluvium into water courses can provide short duration baseflow to rivers and creeks immediately after heavy rains or flooding; however, after larger flood events suitability of these waters for recreation may be limited by other factors.

8.1.6.3 Suitability for Minimal Treatment before Supply as Drinking Water (Raw Water)

The groundwater analytical results, as presented in **Table 8-5**, have been assessed against the Australian drinking water guidelines (NHMRC 2011) to consider the potential health effects of drinking minimally treated groundwater. The EPP (Water) also give a drinking water guideline of 30 milligrams per litre (mg/L) for sodium and 200 mg/L for sulphate. The groundwater quality from the monitoring wells indicates that, in general, groundwater is unsuitable for human consumption. This is due to elevated concentrations of sodium, sulphate, and several dissolved metals (antimony, arsenic, manganese, nickel, and selenium) in some of the groundwater samples collected from the Permian formations. Generally, the groundwater samples contain elevated concentrations of salinity (>1,000 mg/L) which are above the guideline for aesthetics based on the groundwater having an unsatisfactory taste.

Groundwater resources within the survey area would require significant treatment before it could be utilised for drinking. The only local groundwater that may be suitable for human consumption is that which comes from the alluvium associated with the Isaac River. However, concentrations of sodium have been recorded at levels above the EPP (Water) limit of 30 mg/L. It is noted that the concentrations of sodium are less than the Australian drinking water guidelines (NHMRC 2004) limit of 180 mg/L.

The availability of reticulated mains water, rain water tank supplies, and the generally low yield and poor quality of the groundwater bores in the area, are also factors that preclude the usage and potential for usage of the groundwater as a drinking water source.

8.1.6.4 Suitability for Primary Industry Use

Water quality results presented in **Table 8-4** and **Table 8-5** suggest that groundwater within the area is generally suitable for stock drinking water for beef cattle. The higher salinities of the Back Creek Group and Blackwater Group aquifers would potentially result in a loss of production and decline in animal condition and health expected (salinity concentrations >5,000 mg/L). The groundwater in some of the Permian formations has levels of selenium that are slightly elevated above the guideline values.

Although groundwater quality is generally acceptable for stock watering, the generally low sustainable yield of the water bores in all aquifers in the survey area and the salinity of groundwater in the Back Creek and Blackwater Groups precludes the usage and potential for usage of groundwater as a source of irrigation water.

8.1.6.5 Maintenance of Cultural and Spiritual Values

There are no registered groundwater springs or seeps that supply surface water bodies in the survey area. No springs are known to have significant Aboriginal and/or non-Indigenous cultural heritage associations.

However, shallow groundwater in the alluvium may sustain baseflow in the Isaac River for short periods after heavy rains or flooding, although shallow aquifers are ephemeral, only existing for short periods after recharge. The Aboriginal cultural heritage values of that section of the Isaac River within the EIS study area are discussed in **Section 16.1**.

8.2 Potential Impacts and Mitigation Measures

8.2.1 Approach

The impacts on groundwater from the development, operation, closure and post-closure of the project have been evaluated. Potential impact of the mine on the regional groundwater regime was assessed by predictive groundwater modelling. The groundwater model was developed to estimate groundwater extraction (passive seepage and active dewatering for gas control) over the mine life, project drawdown in aquifers, evaluate the zone of influence and direct and indirect impacts of dewatering, and evaluate the possible impact on other groundwater users. The groundwater model was constructed using the geological model, hydraulic parameters determined on site and from literature, and groundwater level information within the survey area. Further details on methodology and modelling information are provided in **Appendix J**.

Mining within the GRB mine complex commenced after the granting of the original Goonyella mining lease (ML1763) in 1971 and the Riverside mining lease (ML1764) in 1978. The North Goonyella mine is located along the strike of the Moranbah Coal Measures immediately north of the EIS study area, with the Moranbah North mine located immediately south. Given the close proximity of these coal mines, this assessment considers the additional and, where possible, the cumulative impact of the project on the current (mine influenced) groundwater resources in the survey area.

While the main aquifers within the area are the coal seams, inflow from the exposed seams to the current GRM pit voids have not been significant. Dewatering in advance of mining is not required for the current open pit or underground workings.

8.2.2 Potential Impacts during Development and Operation

Groundwater drawdown predictions were modelled based on a mine plan developed by BMA in October 2011. The mine plan footprint for the RHM underground expansion option has not changed since that time; however, mine sequencing has been updated to reflect the new project timeline. The BRM mine plan has been updated to account for improved operational efficiencies, including a further extension of the BRM footprints slightly east. These changes to the RHM underground expansion option sequencing and the Broadmeadow extension have the potential to alter extracted groundwater volumes and drawdown over the life of mine but are not anticipated to have a material impact on modelling predictions.

8.2.2.1 Impacts on Regional Groundwater Levels

The project is within the declared Isaac Connors GMA; however, there are few groundwater users locally. During the life of mine, groundwater inflow from the aquifers to the underground mine workings or extraction as part of gas depressurisation will lead to increased drawdown of the potentiometric surface in the vicinity of the mine workings when compared to drawdown from the existing approved coal mines in the area.

Impacts on Permian Formation Aquifers

Dewatering resulting from incidental mine gas (IMG) drainage and groundwater ingress into the mine workings will cause drawdown of groundwater levels as discussed in **Appendix J** and presented in **Figure 8-6** and **Figure 8-7**. Resultant variations in the current groundwater levels, which have already been altered due to existing mine dewatering, were predicted.

Groundwater modelling was used to project drawdown caused by dewatering and IMG drainage of the proposed RHM. Predictive modelling indicates that drawdown of five metres (from pre-RHM mining levels) will occur to a distance of up to four kilometres from the proposed RHM footprint. The drawdown predictions were simulated for the target GMS, allowing for the prediction of the largest zone of influence at the end of mining.

Groundwater drawdown will also occur in the units above the GMS due to induced flow towards the depressurised coal seam and the impact of the goaf resulting in increasing vertical permeability. The extent and degree of drawdown within these overlying units, decreases with increasing distance above the dewatered seams.

The North Goonyella and Moranbah North mines are located along strike and also target the Moranbah Coal Measures to the north and south of RHM, respectively. The cumulative impact of these mines will be to superimpose the drawdown of each mine such that the Moranbah Coal Measures between the mines will be significantly dewatered. No groundwater users were identified between the mines.

Drawdown in bores of five metres or more is considered, in fractured rock aquifers, to have a material impact on bore yield. There are no identified groundwater supply bores within the predicted five metre drawdown zone. Thus, no ‘at risk’ bores have been identified.

Two production bores (Skeleton Bore (NRM Registration 81696), and Cleanskin Gully Bore), on the 'Broadmeadow' property are located outside the predicted five metre drawdown contours as shown on **Figure 8–6**. While it is expected that users of these two bores will still have access to groundwater and not realise a marked change in supply it is recommended that monitoring be conducted to validate predictions.

Additional bores that may potentially be affected by mine dewatering and IMG drainage are the coal seam gas bores themselves. These bores are, however, designed to remove groundwater to allow gas extraction and, hence, mine-induced drawdown should not cause any impacts on these bores.

Impacts on Quaternary and Tertiary Units

Where excavations required for the surface infrastructure and mine access portals encounter Quaternary alluvium near creeks or the Isaac River and / or Tertiary sediments, groundwater inflow may occur (i.e. direct drainage impacts). The aquifers in these units are typically ephemeral and are not considered significant aquifers. Due to the expected low hydraulic gradients (one to two metres) and low conductivity, the drawdown zone of influence, as a result of the direct impacts, is considered to only extend some 10 to 100 metres around excavations. This area around the excavations will remain dewatered, as recognised in the GRB mine complex open-cut pits, as evaporation exceeds ingress.

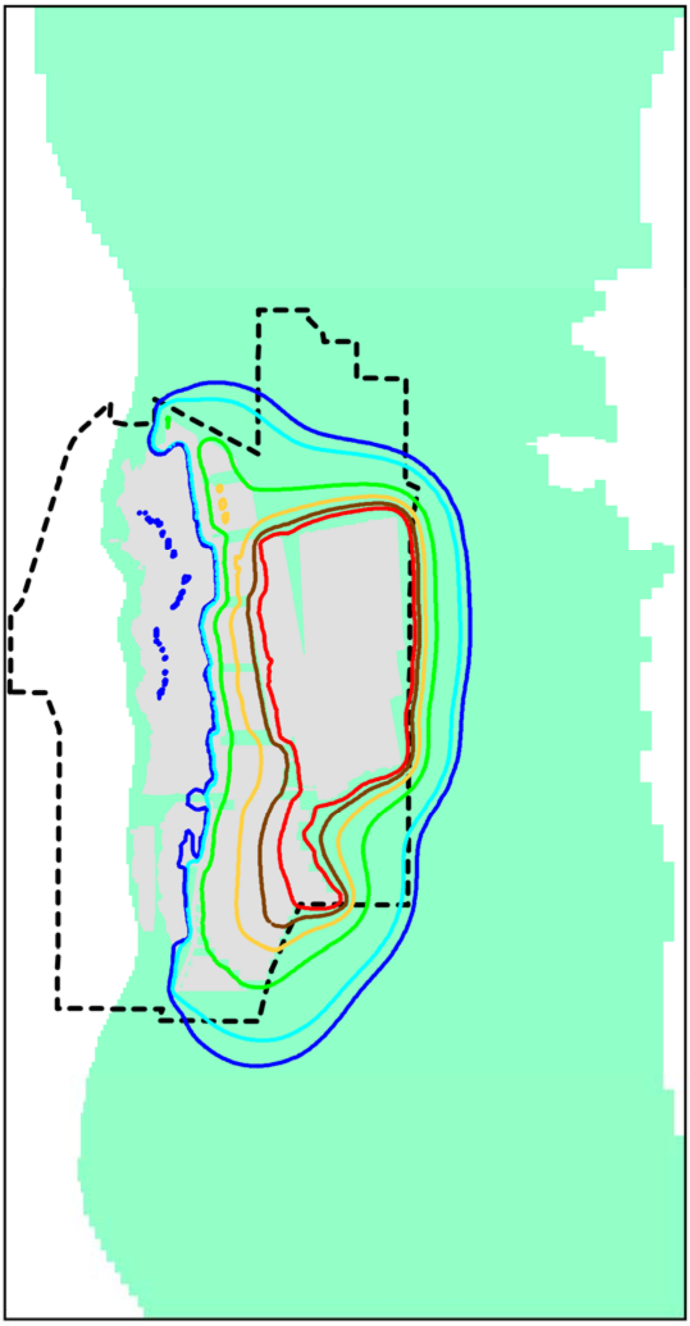
The Quaternary alluvium associated with the Isaac River is considered, based on permeability and water quality, to be the most significant aquifer within the survey area. However, is unlikely to be significantly impacted by groundwater drawdown as there are no major excavations to take place in close proximity to the Isaac River and limited hydraulic connection between the perched water tables in the alluvium and the confined coal seam aquifers (which will be depressurised and dewatered).

Although the numerical model indicates the potential for drawdown of over two metres in the Tertiary/Quaternary units (together referred to as Cainozoic units) (as shown in **Figure 8-8** and **Figure 8-9**), this is not considered to occur in reality due to the ephemeral nature of the Cainozoic units. The model simulations assume fully saturated conditions in the Tertiary sediments and Quaternary alluvium and that these units are in hydraulic connection with the underlying confined aquifers. In reality, due to the short periods over which the aquifers are actually saturated, drawdown due to mining will be much less than predicted.

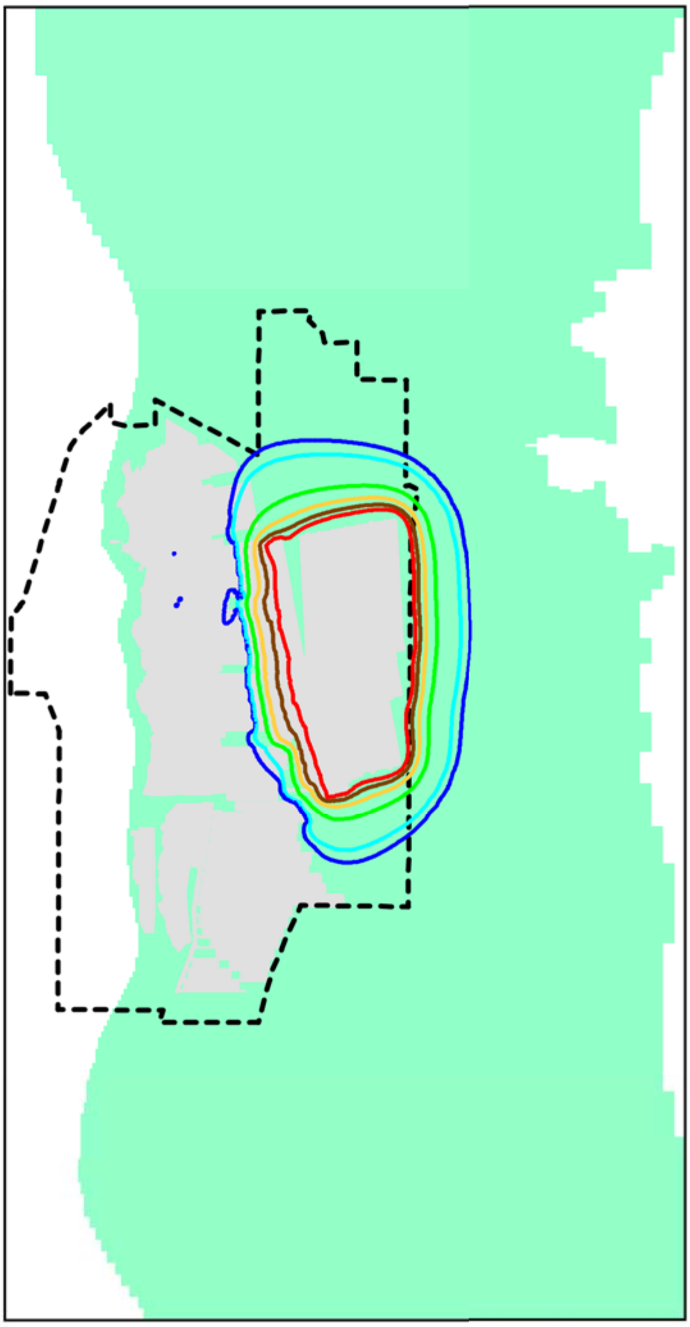
Subsidence is predicted to create cracking at surface (IMC 2011), the clay-rich nature of the Tertiary sediments, Quaternary alluvium, and weathered Permian will, however, self-heal. This will reduce the potential of leakage from surface to the mine workings. Observations at the adjacent BRM appear to confirm this.

All creeks and the Isaac River within the EIS study area are ephemeral and there are no perennial water holes or groundwater dependant ecosystems present, as discussed in **Section 8.1.6.1.** On this basis, impacts on groundwater dependent ecosystems are not expected.

IMG drainage activities are not expected to impact on the Tertiary or Quaternary aquifers as the bores will be sealed where they intersect these aquifers.



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

Drawdown (m)

- 5
- 10
- 50
- 100
- 150
- 200

N W E S

0 3.75 7.5km

Scale

- EIS Study Boundary
- Open-Cut and Underground Mining Operations
- Model Extent

BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

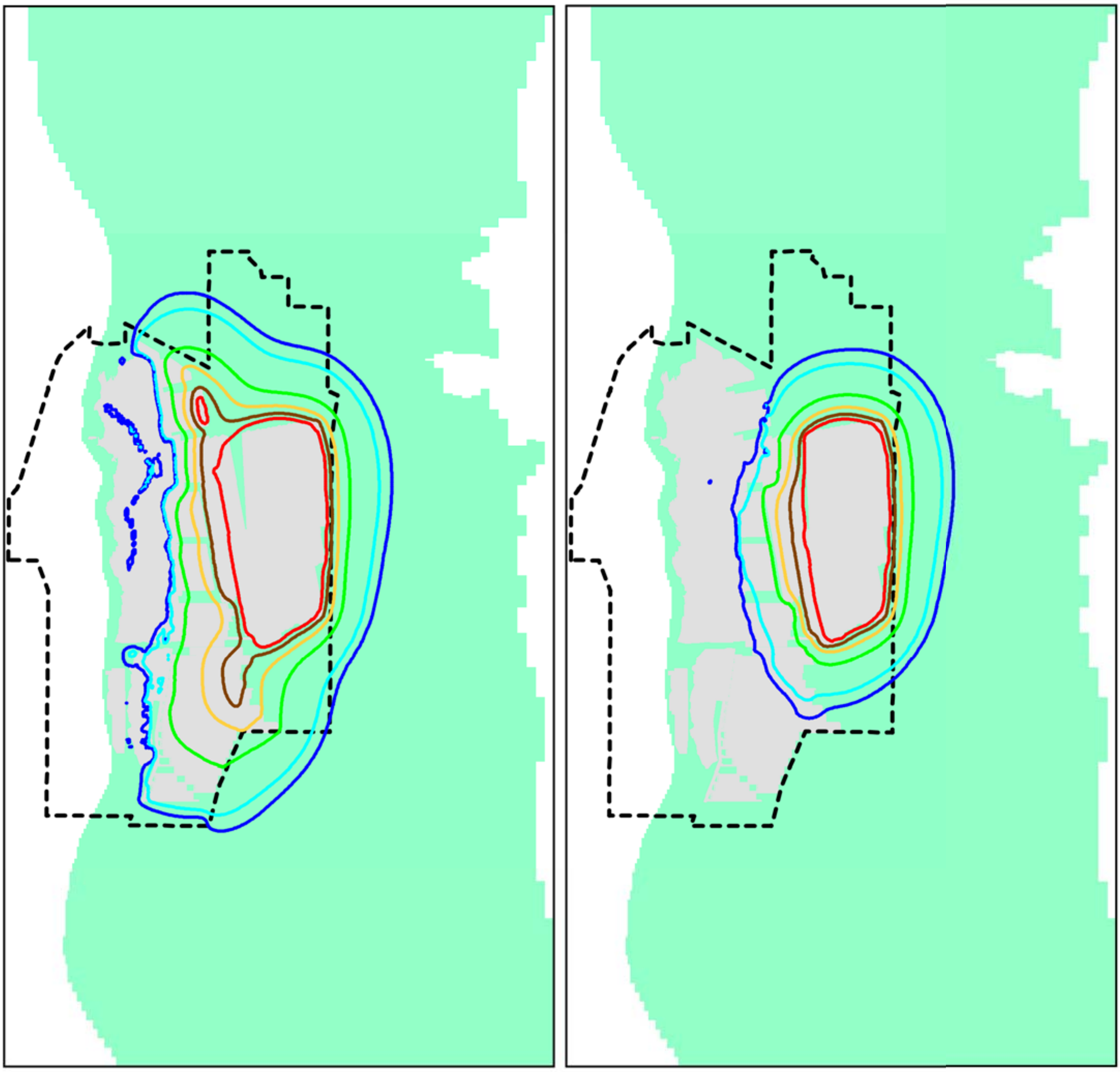
MODELLED GROUNDWATER DRAWDOWN IN GOONYELLA MIDDLE SEAM (MINED SEAM) AT END OF 2040

URS

GROUNDWATER

Figure: **8-6**

File No: **42627136-g-1089.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine

Drawdown as a result of proposed Red Hill Mine

Drawdown (m)

- 5
- 10
- 50
- 100
- 150
- 200

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

N W E S

0 3.75 7.5km
Scale

EIS Study Boundary
Open-Cut and Underground Mining Operations
Model Extent

BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

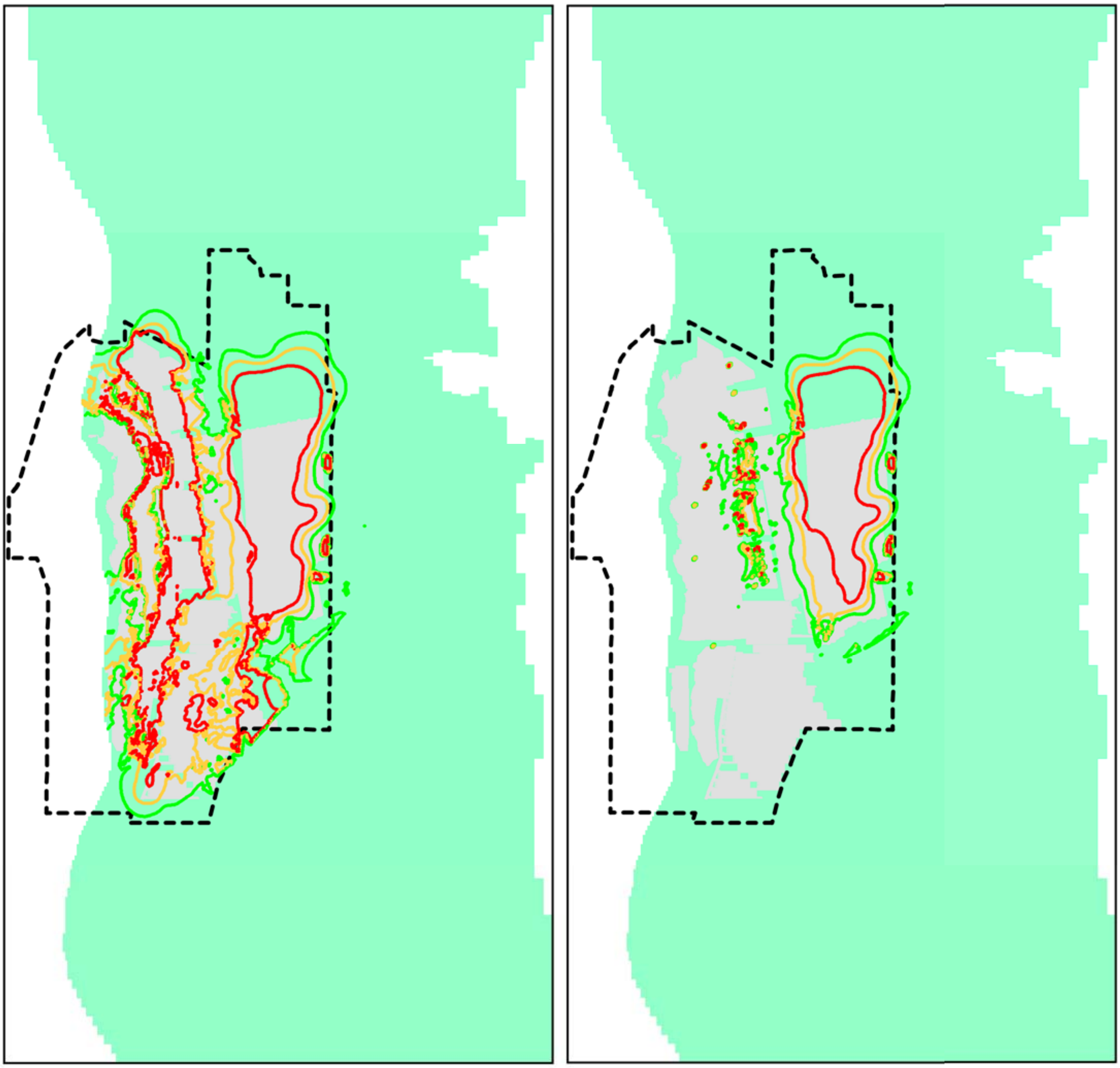
MODELLED GROUNDWATER DRAWDOWN IN GOONYELLA MIDDLE SEAM (MINED SEAM) AT END OF 2068

URS

GROUNDWATER

Figure: **8-7**

File No: **42627136-g-1090.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine

Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

BMA

BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

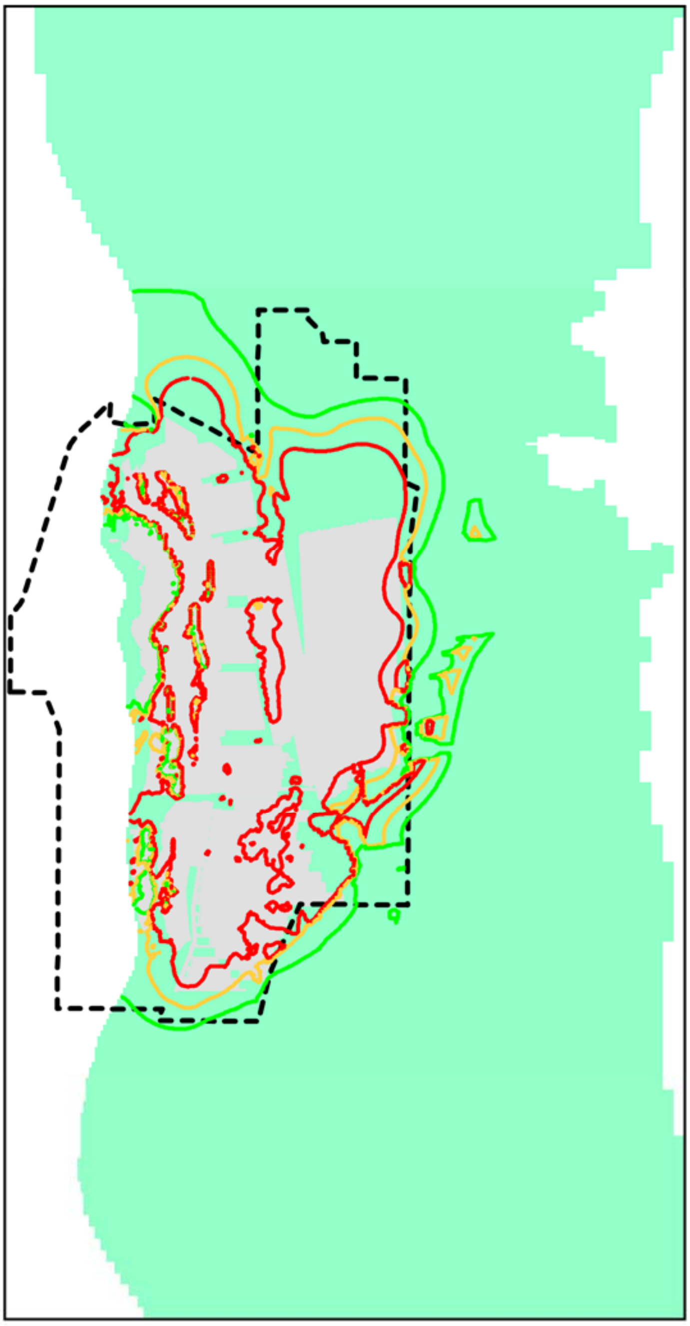
MODELLED GROUNDWATER DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2040

URS

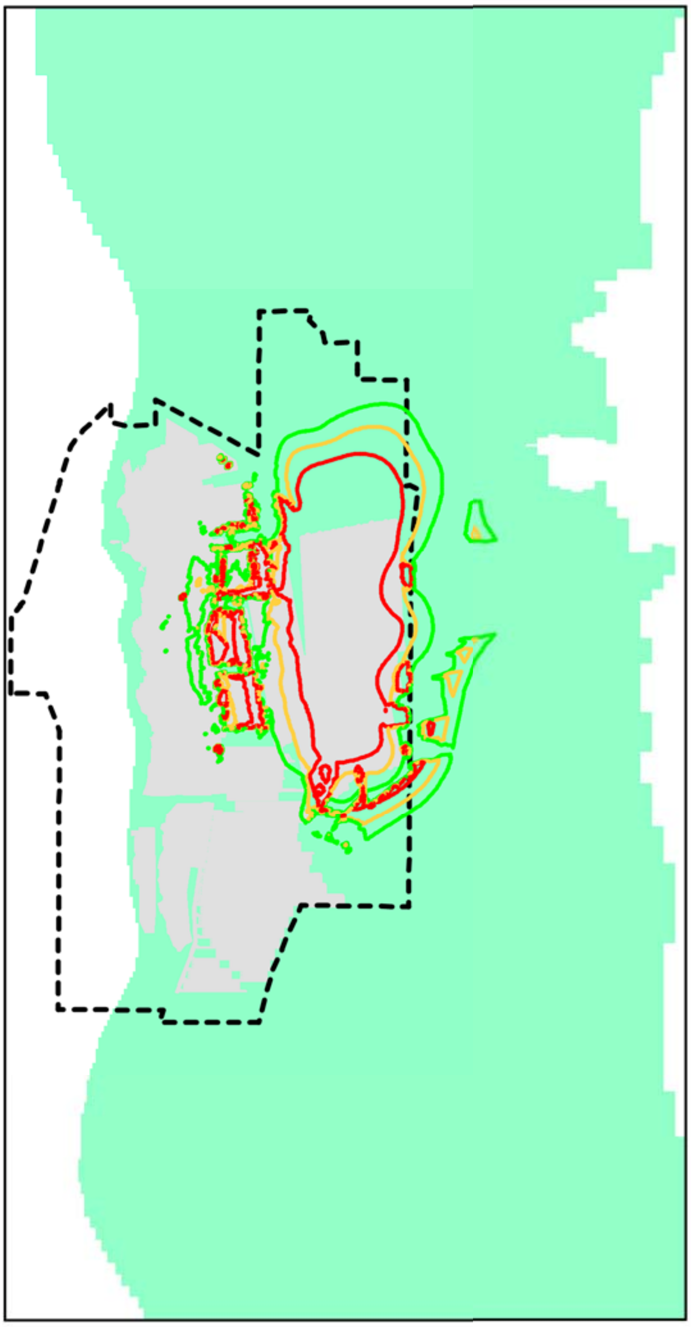
GROUNDWATER

Figure: **8-8**

File No: **42627136-g-1091.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4



Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

Drawdown (m)

- 0.5
- 1
- 2

N W E S

0 3.75 7.5km

Scale

- EIS Study Boundary
- Open-Cut and Underground Mining Operations
- Model Extent

Source: © Mapinfo Australia Pty Ltd and PSMA Australia Ltd., © Copyright Commonwealth of Australia (Geoscience Australia) 2006 , © Copyright The State of Queensland (Department of Natural Resources and Water) 2008, © The State of Queensland (Department of Mines and Energy) 2006-2008, © The State of Queensland (Department of Environment and Resource Management) 2010, Bing Maps © Microsoft Corporation and its data suppliers, Images from Client Oct 2011

BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

MODELLED GROUNDWATER DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2068

GROUNDWATER

Figure: **8-9**

File No: **42627136-g-1092.wor** Drawn: **VH** Approved: **CT** Date: **24-06-2013** Rev.**A** A4

Impacts on Groundwater Quality

During mining operations, groundwater quality within aquifers surrounding the site is not expected to change from pre-mining conditions. This would be a result of all RHM water and waste storage facilities infrastructure being designed, constructed, and managed to ensure little or no potential of seepage. In the event that groundwater contamination did occur contaminant migration off site in the groundwater will not occur. Any potential contaminant plumes would not leave site in the groundwater as during degassing and mining operations, groundwater will be continually extracted from bores or sumps in the underground workings to ensure a safe working environment. This abstraction of groundwater will create a depression in the potentiometric surface around the workings such that the net movement of groundwater is towards the workings during mine operation. This drawdown and alteration in groundwater flow effectively limits the potential for contaminant plumes to migrate off site via groundwater.

Groundwater quality away from the influence of the project will not deteriorate as these resources will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data (with respect to major anions and cations and dissolved metals) indicate that groundwater in the alluvial aquifers and basalt is of similar or better quality when compared to the coal seam aquifers of the Moranbah Coal Measures. Hence, any inadvertent mixing of groundwater during and post mining by induced downward movement from the upper to lower aquifers is unlikely to result in a deterioration of groundwater quality in the Permian aquifers.

Another potential source of contamination for groundwater is through contact with mine waste materials which may be acid forming or leach salt or metal contaminants to groundwater. The geochemical assessment of the coal and mine wastes (waste rock and tailing) undertaken (refer to **Section 6**) indicates that overburden excavated for mine access and reject generated by the proposed mining and coal processing operation is predominantly geochemically benign and is expected to generate seepage and surface run-off with slightly alkaline pH and low-to-moderately salinity following surface exposure. Overburden and reject materials are unlikely to generate acid given the lack of oxidisable sulphur content, excess acid neutralising capacity and existing alkaline pH of these materials.

The waste rock dumps, waste placement areas, coal handling and processing plant (CHPP) and coal stockpiles are located over the relatively saline aquifers of the Permian formations (Moranbah Coal Measures or Back Creek Group), not the fresh water aquifers of the Isaac River Quaternary alluvium or Tertiary sediments. Thus, any potential seepage or runoff is unlikely to result in a marked alteration to groundwater quality of the underlying Permian formations.

The quality of the groundwater in the shallow Cainozoic groundwater resources that may exist within the project footprint have the potential to be impacted by spills or seepage from the mine industrial area (MIA) and waste disposal and fuel storage areas where these are in sufficient quantities to leach through soils to groundwater. Any spills from these areas are typically localised and not regionally significant in terms of groundwater impacts. The risk of groundwater contamination from chemical or fuel storage will be minimised by storage and handling of fuels, oils and other chemicals in accordance with Australian standards and requirements of Material Safety Data Sheets (MSDS).

During mine operation, groundwater quality within aquifers surrounding the mine areas will continue to be suitable for the same purposes applicable during the pre-mining period.

8.2.2.2 Additional Potential Impacts

Compression and/or sealing of the ground surface associated with the construction of roads and building foundations and IMG infrastructure is not expected to greatly alter the permeability of strata immediately beneath the site and, as such, will not markedly reduce rainfall recharge of the underlying aquifers. Works will be limited in the vicinity of the Isaac River, further limiting potential impacts on the Quaternary alluvial aquifer.

Underground mining using conventional longwall mining and thick seam mining methods (longwall top coal caving) will result in subsidence of the overlying strata in the mined-out areas behind the longwall, with fracturing extending from the extraction horizon toward the surface. This caving and subsidence can cause fractures and joints in the overlying strata. Following the passage of longwall panels and stabilisation of subsidence, fracturing in the bulk of the strata will generally close up allowing strata permeability to return to near pre-mining levels (AGE 2002). Within the tensile zone above and adjacent to the longwall panels the vertical and horizontal strata permeability will be significantly and permanently altered due to sub-surface fracturing. In the RHM the fracturing in the Permian units is predicted to extend up to 10 metres from the ground surface (IMC 2011).

Methods of degassing the coal in advance of mining are currently being developed for the project, and are likely to include installation of gas drainage wells (vertical or surface to in-seam). The drilling and installation of gas drainage wells has the potential to impact on groundwater (through water quality mixing, gas migration pathways - if not sealed correctly - resulting in composite potentiometric heads) by creating potential pathways for leakage between formations.

Permanent subsurface structures such as building foundations and road embankments can impede shallow groundwater flows and cause localised groundwater restrictions and waterlogging. The project does not require extensive subsurface structures in the vicinity of the Isaac River and associated alluvial aquifer, where possible (seasonal) shallow groundwater can be intersected. The detailed design phase of the project will, however, consider shallow groundwater occurrence and include any necessary engineering solutions.

8.2.3 Potential Impacts Post-Mining

The main features of the final landform after mining ceases will comprise partially to totally filled mine voids in the underground workings, and subsidence troughs on the surface.

As with the impacts during mining, the increased permeability and storage for groundwater in the goaf will remain after mining.

8.2.3.1 Impacts on Regional Groundwater Levels

The remnants of the mine void will collect and accumulate water from groundwater ingress through the walls and goaf of the final workings. There is also the potential for groundwater ingress to occur from surface through leakage down the ventilation shafts, the mine access drift, old exploration holes or abandoned bores. These pathways facilitate groundwater rebound post mining.

Typically, the mine workings will fill up and groundwater levels will recover over time. The groundwater system will readjust to the new (altered and enhanced) aquifer conditions surrounding and within the mined area with some localised changes to pre-mining characteristics. Groundwater levels and piezometeric pressures within the regional aquifers will, over time, attain a new equilibrium level. This new equilibrium for the groundwater system will have a different potentiometric surface from that which was present pre-mining, owing to the presence of the old workings and the different hydrogeological parameters of the goaf.

A detailed study of groundwater level recovery within RHM has not been conducted because the closure requirements for the GRM will have a significant impact on recharge to groundwater and the rate of groundwater recovery. Groundwater levels are expected to recover within RHM after closure during the continued operation of GRM, and further work will need to be undertaken throughout the GRM mine life to determine the hydrological regimes, and the expected water quality of the mine voids. It is considered that the groundwater levels will recover in RHM, over time, to the base of the GRB mine complex open pits. The GRB mine complex final voids will, based on size and climate conditions (evaporation exceeding rainfall), permanently alter groundwater flow patterns towards the GRB mine complex final voids.

8.2.3.2 Impacts on Groundwater Quality

A rise in the groundwater salinity within the RHM void may occur as a result of atmospheric weathering of the exposure of wall, roof and floor rock during mining. However, as discussed above, any increase in groundwater salinity is expected to be minor compared to the natural salinity of the groundwater in the Permian formations. Current and previous geochemical analysis in the Moranbah Coal Measures lithology show that there is low acid generation potential, thus there is a low risk that metals will be mobilised into the groundwater.

Post-mining water quality within all aquifers surrounding the EIS study area is expected to remain similar to pre-mining water quality.

8.2.4 Mitigation Measures for Potential Impacts

Groundwater monitoring bores were previously installed around the EIS study area as shown in **Figure 8–3** and **Figure 8–4**. Additional groundwater monitoring bores and vibrating wire piezometers (VWPs) were also installed by BMA in early 2012. Further groundwater monitoring bores are to be installed down-gradient of mine water and waste storage facilities with locations to be determined after finalisation of the site layout. Further monitoring will be undertaken prior to the commencement of mining of the RHM underground expansion option to enable the long term monitoring of groundwater levels and groundwater quality, as well as to provide data for updates of the groundwater model.

Routine monitoring during the mining operation will provide early warning of any variation in response of the groundwater system to that predicted. This will enable BMA to undertake mitigation measures to minimise impact on surrounding groundwater users and the environment, such as the implementation of make-good measures. In addition, the groundwater monitoring will enable the identification of any cumulative groundwater level drawdown impacts as a consequence of other mining operations in the area.

8.2.4.1 Groundwater Monitoring Program

A groundwater monitoring network and program will be developed and implemented for the RHM underground expansion option to detect any marked change to groundwater quality due to mining activities. This will be consistent with the current suitability of the groundwater for agricultural use (stock watering), limited domestic use, and any discharge to surface waters that may occur after significant wet weather events.

Prior to commencement of mining for the RHM underground expansion option, at least 12 groundwater monitoring events will be undertaken, evenly spread across wet and dry seasons for at least two years. The monitoring events will record:

- groundwater levels; and
- groundwater quality with analysis of the parameters: - pH, electrical conductivity (EC), total dissolved solids (TDS), major cations and anions, nutrients (total nitrogen, nitrous oxides, ammonia, phosphorous), selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc), and total petroleum hydrocarbons (for bores monitoring potential fuel spill / seepage sources).

In addition, continuous groundwater level monitoring will be conducted using vibrating wire piezometers automatically recording water levels at regular intervals.

On completion of the initial 24 month baseline monitoring, groundwater trigger levels, based on the 85th percentile value of groundwater quality results and groundwater contaminant limits based on the 99th percentile of groundwater quality results will be determined for each of the aquifers identified to be impacted by the project.

During mining operations, groundwater monitoring will continue, including:

- Monitoring of groundwater levels in standpipe monitoring bores and vibrating wire piezometers.
- Groundwater quality sampling undertaken at least once every wet season and once every dry season with analysis of the parameters: - pH, EC, TDS, major cations and anions, nutrients, selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc), and, if a significant fuel spill has occurred, total petroleum hydrocarbons (for bores monitoring potential fuel spill / seepage sources).

If groundwater quality results exceed trigger levels set out in the environmental authority, monitoring will be repeated within 30 days. If concentrations exceed trigger levels in the second sampling event then an investigation into cause, optimum response, and the potential for environmental harm will be conducted and mitigation measures developed and implemented to address the outcome of the investigation. These mitigation measures will be reported to the administering authority.

Additional monitoring will be conducted in down-gradient bores in the event of a significant spill of fuels or other contaminants with potential to cause groundwater contamination.

Measurement of daily precipitation, evaporation, and gas drainage and mine dewatering volumes will be undertaken through operations.

Groundwater monitoring and sampling will be conducted by a suitably qualified and experienced professional in accordance with the then DERM Monitoring and Sampling Manual (2010), or subsequent updated versions; and the Australian/New Zealand Standard (AS/NZS) 5667.11:1998 for water quality – sampling Part 11; guidance on sampling groundwater.

Monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate groundwater trends.

An annual review of the monitoring program will be conducted by a suitably qualified and experienced hydrogeologist. This annual review of the monitoring program will be conducted to evaluate the effectiveness of each monitoring location, to assess where new locations and modifications to the monitoring program may be needed, and to evaluate impacts that may be occurring. These data will, on a regular basis (no longer than three years), be used to validate model predictions. Monitoring reports will be submitted to the administering authority as set out in the environmental authority.

Post-mining groundwater monitoring will be subject to detailed closure/relinquishment conditions. It is expected that during the operational phase of the project, the groundwater data collected and revised predictive modelling for the region will be comprehensive enough to accurately predict the long term recovery of the aquifers. This will assist in the development and implementation of the closure strategy and the refinement of post-mining groundwater monitoring programs.

8.2.4.2 Impacts on Nearby Groundwater Users

While groundwater model predictions do not indicate any significant impacts on adjacent groundwater users, should a detrimental impact on landholder groundwater supplies be detected, and shown to be related to the project operations, then BMA will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alternate water supplies. To this end, BMA will update its groundwater census of bores on properties within the predicted drawdown cone prior to commencement of mining, and enter into make-good agreements with landholders specifying trigger levels and appropriate responses.

Options for alternate supplies include:

- installations of new pumps capable of extracting groundwater from greater depth within existing bores;
- deepening of existing bores;
- installation of a new bore at another location on the property; or
- provision of piped water sourced from the mine (i.e. surplus water from the mine pit void dewatering program, depending on quality).

The specific arrangements for affected properties will be discussed with each relevant landholder with a view to reaching a mutually acceptable agreement.

8.2.4.3 Seepage from Stockpiles and Surface Water Control Structures

Good environmental practice requires that reasonable effort be made to minimise seepage from stockpiles and surface water control structures wherever this may affect the groundwater system. All mine water storages will be constructed in accordance with the NRM (2002) Queensland Dam Safety Management Guidelines. These guidelines include requirements for management of seepage from mine water storages.

The surface water runoff collection system from the MIA and CHPP will be managed as a non-release system with stormwater returned to the mine water management system. Raw and product coal stockpiles will be contained within hardstand or compacted areas and drainage will be directed to the mine water management system.

Early detection of significant seepage will enable management of any potential problems. Potential seepage from the project surface water management system (such as the IMG water production dam for gas drainage works) will be regularly assessed through the monitoring bore network on site, including down-gradient of all potential seepage sources.

In the unlikely event of groundwater impact, mitigation strategies will include some or all of the following measures (depending on the specific requirements):

- investigation of water management system integrity;
- removal of contaminant source and repair / redesign of any water management structures as required;
- installation of and pumping from, groundwater interception wells; and/or
- installation of and pumping from groundwater interception trenches.

8.2.4.4 Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage and handling will be designed to contain spills and procedures will be in place to minimise likelihood of spills and provide a rapid response in the event that spills occur. Spill kits and spill clean-up training will be available on site.

Installation and monitoring of the monitoring bore network on site, including down-gradient of all potential spill areas, will enable early detection of any contaminated seepage.

Further information on the prevention and management of spills is provided in **Section 5.4**.

8.2.4.5 Installation of Gas Drainage Bores

Gas drainage wells will be designed and constructed in accordance with industry standards, with the goal of maintaining hydraulic isolation between discrete water bearing formations. This will therefore inherently mitigate the risk of gas migration into overlying aquifers and/or releases at the surface. In addition, the integrity of the wellhead and casing will be monitored as part of normal operations.

8.2.4.6 Closure and Post-closure

There are no specific groundwater management requirements in relation to closure and post closure other than the continued commitment to make-good any impacts on groundwater resources, as discussed above. If significant groundwater drawdown has occurred, groundwater levels may continue to be monitored to track recovery and validate predictive groundwater modelling.